SPECIAL ISSUE IN REMEMBRANCE OF JOEL WARM

The Effects of Event Rate on a Cognitive Vigilance Task

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Objective: The present experiment sought to examine the effects of event rate on a cognitive vigilance task.

Background: Vigilance, or the ability to sustain attention, is an integral component of human factors research. Vigilance task difficulty has previously been manipulated through increasing event rate. However, most research in this paradigm has utilized a sensory-based task, whereas little work has focused on these effects in relation to a cognitive-based task.

Method: In sum, 84 participants completed a cognitive vigilance task that contained either 24 events per minute (low event rate condition) or 40 events per minute (high event rate condition). Performance was measured through the proportion of hits, false alarms, mean response time, and signal detection analyses (i.e., sensitivity and response bias). Additionally, measures of perceived workload and stress were collected.

Results: The results indicated that event rate significantly affected performance, such that participants who completed the low event rate task achieved significantly better performance in terms of correction detections and false alarms. Furthermore, the cognitive vigil utilized in the present study produced performance decrements comparable to traditional sensory vigilance tasks.

Conclusion: Event rate affects cognitive vigilance tasks in a similar manner as traditional sensory vigilance tasks, such that a direct relation between performance and level of event rate was established.

Application: Cognitive researchers wishing to manipulate task difficulty in their experiments may use event rate presentation as one avenue to achieve this result.

Keywords: cognition, information processing, human performance

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INTRODUCTION

Vigilance, or the ability to sustain attention for extended periods of time (Davies & Parasuraman, 1982), has been of great importance to human factors researchers over the past 70 years (Fraulini, Hancock, Neigel, Claypoole, & Szalma, 2017). Previous research has consistently demonstrated that performance typically declines with time on task, which is a phenomenon commonly denoted as the vigilance decrement (Davies & Parasuraman, 1982; Mackworth, 1948; See, Howe, Warm, & Dember, 1995). It has been reported that the decrement can manifest as fewer correct detections, slower response times, and decreased perceptual sensitivity (See et al., 1995; Hancock, 2013; Warm, Matthews, & Parasuraman, 2009). Moreover, consequences of the vigilance decrement have resulted in nuclear meltdowns (Reinerman-Jones, Matthews, & Mercado, 2016) and breaches of homeland security (Hancock & Hart, 2002; Meuter & Lacherez, 2016) in organizational contexts. As the consequences of the vigilance decrement can result in perilous outcomes, it is unsurprising that previous research has extensively focused on factors that attenuate (i.e., rest breaks, Helton & Russell, 2015, 2017; monetary incentives, Smith, Lucaccini, & Esptein, 1967; and knowledge of results, Szalma, Hancock, Dember, & Warm, 2006) or exacerbate (i.e., increasing task load and event rate, Parasuraman, Warm, & Dember, 1987; Szalma, 2009; 2011; Warm, Parasuraman, & Matthews, 2008) the decrement.

Although the vigilance decrement may be the most compelling finding associated with vigilance (Fraulini et al., 2017; Warm et al., 2008), it has also been well documented that these tasks induce consistent patterns of high levels of workload and stress (Warm, Dember, & Hancock, 1996; Warm et al., 2008). Specifically, it has been demonstrated that mental demand and frustration are the major contributors to the high levels of perceived workload in vigilance (i.e., Hancock & Warm, 1989; Reinerman-Jones et al., 2016; Szalma et al., 2004, 2006; Warm et al., 1996, 2008). Furthermore, stress (as comprised of distress, task engagement, and worry, Matthews et al., 1999, 2002) also exhibits a pre-post task profile associated with vigilance—such that task engagement and worry tend to decline while distress tends to escalate as a function of the vigil (i.e., Reinerman-Jones et al., 2016; Warm et al., 2008).

In addition to the profile of workload and stress associated with vigilance, previous research has also established a taxonomy of vigilance task features (i.e., Parasuraman, 1979; Parasuraman & Davies, 1977; See et al., 1995). Currently, the taxonomy of vigilance is comprised of four dimensions that influence detection performance (Parasuraman & Davies, 1977, but see See et al., 1995): source complexity, signal discrimination type, sensory modality, and event rate. Signal discrimination type includes successive (i.e., comparing stimuli with representations held in memory) and simultaneous (i.e., distinguishing signals from nonsignals by comparing stimulus elements presented concurrently) stimulus discriminations. Importantly, previous research has demonstrated that successive discrimination tasks tend to impose greater memory load relative to simultaneous discrimination tasks (Parasuraman & Mouloua, 1987). Sensory modality traditionally refers to the mode in which the stimuli are presented (i.e., visual versus auditory), such that auditory displays are associated with steeper performance decrements. Source complexity refers to the number of displays that are monitored (i.e., one display versus four displays), such that more displays to be monitored result in poorer performance and exacerbate the decrement.

Event rate, or the rate of presentation of nontarget stimulus events (Parasuraman, 1979), has been identified as one of the most important factors affecting vigilance performance (Parasuraman & Davies, 1977); thus it is no surprise that one of the most influential scientists to the field of vigilance extensively examined this effect. Joel Warm demonstrated that the quality of vigilance task performance is inversely related to event rate (Galinksy, Rosa, Warm, & Dember, 1993; Warm & Jerison, 1984), such that higher event rates are associated with steeper decrements (Jerison & Pickett, 1964; Lanzetta, Dember, Warm, & Berch, 1987). Numerous studies have replicated this effect to demonstrate that the presentation rate of events may be implemented to manipulate task difficulty (Guralnick, 1973; Jerison & Pickett, 1964; Meuter & Lacherez, 2016; Mouloua & Parasuraman, 1995; Parasuraman, 1979; Parasuraman & Giambra, 1991; Rose, Murphy, Schickedantz, & Tucci, 2001; Smith, Mikulka, Freeman, & Scerbo, 2002; Yadav, Singh, & Tiwari, 2015).

Although Parasuraman and Davies (1977) have classified a "low" event rate as under 24 events per minute and a "high" event rate as more than 24 events per minute, previous studies have manipulated these parameters to extend the spectrum of what is quantified as "high" and "low." For instance, one study indicated that an event rate of 24 events per minute demonstrated no significant differences in performance when compared with an event rate of 12 events per minute (Smith et al., 2002), suggesting that 24 events per minute may be sufficient to deem as a "low" event rate. Moreover, although many studies utilize an event rate of over 30 events per minute to induce a high event rate condition (Galinsky, Dember, & Warm, 1989; Jerison & Pickett, 1964; Mouloua & Parasuraman, 1995; Parasuraman, 1979; Parasuraman & Giambra, 1991; Rose et al., 2001), several employed an event rate of 40 events per minute to consistently demonstrate the inverse relationship of event rate and vigilance task performance (Galinksy et al., 1989; Mouloua & Parasuraman, 1995; Parasuraman & Giambra, 1991; Rose et al., 2001).

Event rate is an integral component of the vigilance taxonomy (Parasuraman & Davies, 1977; Parasuraman, 1979), and this effect has been consistently observed in relation to the other components of the taxonomy as well. For instance, both successive and simultaneous vigilance tasks produce the traditional inverse relationship between event rate and detection performance (Parasuraman & Davies, 1977; See et al., 1995). However, most experiments that employ event rate as a manipulation of task difficulty have done so with a sensory task (e.g., Guralnick, 1973; Jersion & Pickett, 1964; Stearman & Durso, 2016), whereas relatively few studies have examined the effects of event rate on performance of a cognitive vigil (Mouloua & Parasuraman, 1995; Smith et al., 2002; Warm, Fishbein, Howe, & Kendell, 1976).

Sensory tasks are defined by sensory-perceptual discriminations (e.g., duration, pitch, brightness; Davies & Parasuraman, 1982), whereas cognitive tasks are described as stimulus discriminations that require symbolic processing (e.g., letters, words, or digits, Mouloua & Parasuraman, 1995). See et al. (1995) suggested that the taxonomy should be extended to include the effects of cognitive versus sensory tasks (see also Warm, Howe, Fishbein, Dember, & Sprague, 1984). It has been previously argued that cognitive- and sensory-based vigilance tasks may differ in performance efficiency, such that although sensory vigils show consistent performance decrements, cognitive vigils tend to remain stable (Davies & Tune, 1969; Deaton & Parasuraman, 1993; Dember, Warm, Bowers, & Lanzetta, 1984; See et al., 1995). Furthermore, the *vigilance increment* has been associated with simultaneous cognitive vigilance tasks (Dember et al, 1984; Lysaght et al., 1984; See et al., 1995; Warm et al., 1984), whereas successive cognitive vigils have demonstrated typical performance decrements (Claypoole & Szalma, 2018, in press; Mouloua & Parasuraman, 1995).

The effects of event rate on cognitive vigilance are unclear. It has been suggested that the event rate effects may not occur in the presence of cognitive stimuli (Warm et al., 1976), especially when successive discrimination is required (See et al., 1995, but see Claypoole & Szalma, 2018; Mouloua & Parasuraman, 1995). However, it has been noted that simultaneous cognitive vigilance tasks have produced traditional event rate effects, such that the magnitude of the decrement is positively related to event rate (See et al., 1995). However, Warm himself has argued that the current vigilance taxonomy is possibly only applicable to sensory-based tasks as there is limited research that employ cognitive-based tasks; Warm has suggested that researchers should consider this dimension of cognitive versus sensory in order to further develop the vigilance taxonomy (Warm et al., 1984). Therefore, further empirical evidence on the relationships between cognitive vigils and other factors of the taxonomy, such as event rate, that extend Warm's major contributions are needed.

THE PRESENT STUDY

The present experiment sought to examine the effects of event rate on a successive cognitive vigilance task in order to afford further empirical evidence that the presentation rate of events can be used to manipulate task difficulty in cognitive-based vigils. Based on recent work (Claypoole & Szalma, 2018, in press) it was hypothesized that the cognitive vigil used in the present study would exhibit traditional performance decrements associated with sensory vigilance tasks as described by Warm et al. (2008). Furthermore, it was postulated that an inverse relationship between performance and event rate would be observed, such that a high event rate would be associated with a larger performance decrement (See et al., 1995).

As there is limited prior research that employs cognitive vigils, specifically those that manipulate event rate, it is unclear how the perceived workload and stress associated with cognitive-based vigilance tasks will be affected. Based on recent work (i.e., Claypoole & Szalma, 2018) it was hypothesized that the cognitive vigil used in the present experiment would impose high workload (i.e., Grier, 2015) and that the traditional pre-post task profile of stress would be observed (i.e., lower task engagement and worry, higher distress as a function of the vigil).

METHOD

Observers

Overall, performance data from 84 observers (56 female) were collected. Observers averaged 20.2 years in age (SD = 5.09 years, Range: 18–53 years), and were all undergraduates at the University of Central Florida. Observers received course credit for completing the study, however, participation was on a voluntary basis and observers could withdraw from the study without penalty at any time. Informed consent was obtained from each observer, and this research complied with the American Psychological Association Code of Ethics which was approved by the institutional review board at the University of Central Florida.

Conditions

The present study manipulated task difficulty by manipulating event rate in a successive cognitive vigilance task. The presentation rate of nontarget stimulus events was selected from prior research examining the effects of event rate on vigilance task performance (Galinksy et al., 1989; Mouloua & Parasuraman, 1995; Parasuraman & Davies, 1977; Parasuraman & Giambra, 1991; Rose et al., 2001; Smith et al., 2002). Two conditions were utilized to examine this effect: *Low Event Rate* and *High Event Rate*. In the *Low Event Rate* condition, stimuli were presented for 1,000 ms immediately followed by a 1,500 ms interstimulus interval (ISI) for a trial duration of 2,500 ms and an event rate of 24 events/minute (signal probability = 0.035). In the *High Event Rate* condition, stimuli were presented for 1,000 ms immediately followed by a 500 ms ISI for a trial duration of 1,500 ms and an event rate of 40 events/minute (signal probability = 0.021).

Vigilance Task

The task parameters and stimuli used in the present experiment were adapted from previous research using cognitive-based vigilance tasks that have produced a reliable decrement (i.e., Claypoole & Szalma, 2018; Warm et al., 1976; Warm & Jerison, 1984). Observers were required to monitor a computerized display of repeated two-digit numbers. Observers were instructed to respond by pressing the space bar as quickly as possible when a critical signal appeared on the screen (i.e., a two-digit number where the difference between the two digits was either "0" or +/- "1"; Claypoole & Szalma, 2018). Each stimulus was presented for 1,000 ms and was followed by an ISI (a blank screen) that lasted either 500 ms (i.e., *High Event Rate* Condition) or 1,500 ms (i.e., *Low Event Rate* Condition) depending on the condition. Observers could respond at any time during the stimulus duration (i.e., either 1,500 ms or 2,500 ms). In both 24-minute vigilance tasks, there were a total of 20 critical signals across four periods on watch (i.e., five critical signals in each 6-minute period on watch).

Measures

Dundee Stress State Questionnaire (DSSQ; Matthews et al., 2002; Matthews, Szalma, Panganiban, Neubauer, & Warm, 2013): Perceived stress was measured both prior to and after the vigil. The DSSQ is comprised of 11 scales that encompass three broad secondary factors: distress, task engagement, and worry. These broad secondary factors echo the affective, cognitive, and motivational/energetic dimensions of stress. Task engagement is argued to be associated with effort, distress is argued to be associated with cognitive capacity, and worry is argued to be associated with self-evaluation. Typically, vigilance tasks are associated with a reduction in task engagement and worry and are associated with a rise in distress (Warm et al., 2008).

NASA Task Load Index (Hart & Staveland, 1988): Perceived mental workload was measured following the conclusion of the vigil. The NASA-TLX is comprised of six subscales: temporal demand, mental demand, physical demand, frustration, effort, and perceived performance. Participants were first required to provide a rating of 0–100 on each of the subscales, and then were required to judge the relative importance of each subscale through pairwise comparisons. Together, these ratings and pairwise comparisons were used to compute a global workload score.

Procedure

The procedure utilized in the present experiment was identical to the procedure reported by Claypoole and Szalma (2018). Observers were required to surrender any time pieces and cellular devices when they arrived to the laboratory. Observers were randomly assigned to one of the two experimental conditions. In both conditions, observers first completed a set of questionnaires (pretask DSSQ, demographics questionnaires) prior to the vigil. The researcher then provided an overview of instructions, reviewed example stimuli, and answered any questions before exiting the room. Observers completed a 5-minute practice task to familiarize them with the task. Immediately after the practice task, the observers began the 24-minute vigil. After the vigil was completed, observers were instructed to alert the research assistant so that they could prepare posttask questionnaires (i.e., posttask DSSQ, NASA-TLX) for the observers to complete. At the conclusion of the questionnaires,

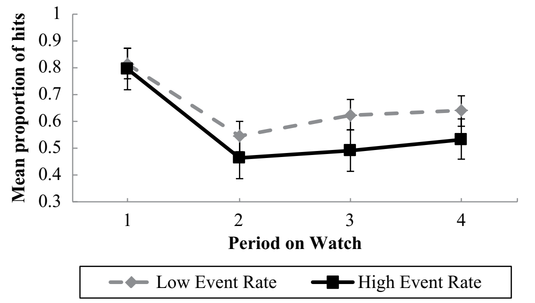

Figure 1. The proportion of hits as a function of period on watch and experimental condition.
Note. Error bars are standard errors.

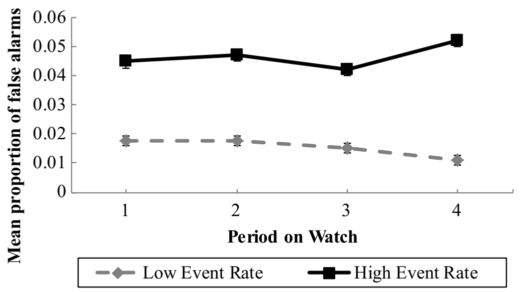

Figure 2. The proportion of false alarms as a function of period on watch and experimental condition.
Note. Error bars are standard errors.

observers were debriefed and thanked for their participation. On average, the experiment took no longer than an hour to complete.

RESULTS

Statistical Analyses

Consistent with previous research (i.e., Claypoole & Szalma, 2018), each dependent measure of performance (i.e., correct detections, false alarms, and mean response time) was analyzed by a 2 (condition) by 4 (period) mixed analysis of variance (ANOVA), with repeated measures on the second factor. Significant condition by period interactions were further analyzed by testing the simple effects of period within condition. Furthermore, the proportion of correct detection and false alarms were used to compute nonparametric (i.e., Craig, 1979) indices of sensitivity (*A'*) and response bias (β''_D, Macmillan & Creelman, 2005).

Measures of perceived stress (i.e., DSSQ) and workload (i.e., NASA-TLX) were also analyzed. The NASA-TLX was analyzed by a one-way ANOVA. The DSSQ was analyzed by a 2 (Condition) by 2 (phase) mixed ANOVA, with repeated measures on the second factor. The scores were calculated as suggested by the authors [i.e., Matthews et al., 1999, 2002; Z = ((score means) – (Normative means) / (Normative SD)) for each of the 11 primary scales]. Z-scores were then used to compute factor scores for the three broad secondary factors: Distress, Task Engagement, and Worry. In total, performance data from 84 participants (56 female) were collected across both conditions: *Low Event Rate* (42, 28 female); *High Event Rate* (42, 28 female).

Performance

The proportion of signals detected significantly decreased across both conditions as a function of period on watch, $F(3, 246) = 47.795$, $p < .001$, $\eta^2p = .368$. There was not a statistically significant interaction between condition and period on watch, $F(3, 246) = 1.603$, $p = .189$, $\eta^2p = .019$. However, the results did indicate a significant difference between conditions for the overall proportion of signals detected, $F(1, 82) = 4.221$, $p = .043$, $\eta^2p = .049$ (see Figure 1). These results indicate that correct detection performance was higher for participants in the *Low Event Rate* condition relative to those in the *High Event Rate* condition.

The proportion of false alarms did not change significantly as a function of period on watch, $F(3,246) = .137$, $p = .938$, $\eta^2p = .002$. The interaction between condition and period was not statistically significant, $F(3, 246) = .560$, $p = .642$, $\eta^2p = .007$. However, the results did indicate a significant difference between conditions for the overall proportion of false alarms, $F(1, 82) = 4.555$, $p = .036$, $\eta^2p = .053$ (see Figure 2). The results indicated that participants in the *Low Event Rate* condition committed fewer false alarms, and thus achieved better performance, than those in the *High Event Rate* condition.

Mean response time increased significantly across both conditions as a function of period on watch, $F(3, 213) = 31.865$, $p < .001$, $\eta^2p = .310$. The interaction between condition and period was also statistically significant, *F*(3,

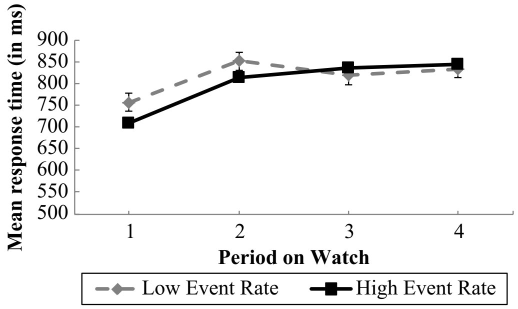

Figure 3. Mean response time as a function of period on watch and experimental condition.
Note. Error bars are standard errors.

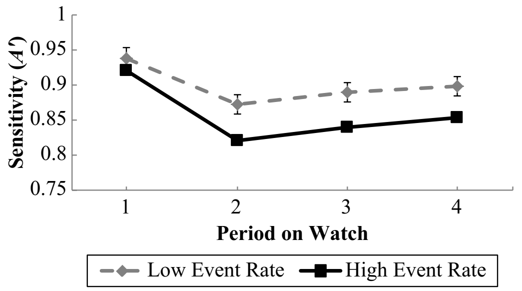

Figure 4. Sensitivity (*A'*) as a function of period on watch and experimental condition.
Note. Error bars are standard errors.

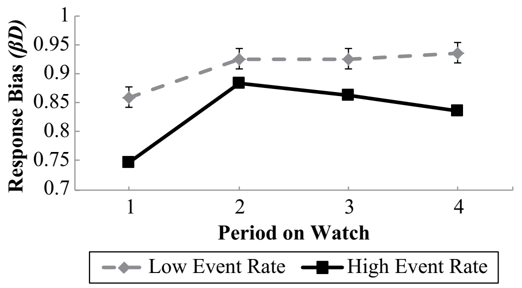

Figure 5. Response bias (β''_D) as a function of period on watch and experimental condition.
Note. Error bars are standard errors.

213) = 4.413, p = .005, η^2p = .059. Tests of the simple effects of period within each event rate condition indicated a significant increment in response time in each case, *Low:* F(3,105) = 8.624, p < .001, η^2p =.198; *High:* F(3,108) = 30.622, p < .001, η^2p =.460. However, the effect of period on watch was substantially stronger in the high event rate condition relative to the low event rate condition. Importantly, there were no significant differences among conditions for the overall mean response time, F(1, 71) = .220, p = .640, η^2p = .003 (see Figure 3). The average mean response time for those in the *Low Event Rate* condition was M = 821.768 (SD = 171.561), and the average mean response time for those in the *High Event Rate* condition was M = 802.919 (SD = 171.561). These results suggest that across both conditions, participants had enough time to respond to the stimuli, and any change in performance was not produced by a data-limited process (i.e., Norman & Bobrow, 1975).

Sensitivity significantly decreased across both conditions as a function of period on watch, F(3, 246) = 31.093, p < .001, η^2p = .275. There was not a statistically significant interaction between condition and period, F(3, 246) = 1.479, p = .221, η^2p = .018, but there was a significant difference between conditions in sensitivity, F(1, 82) = 7.298, p = .008, η^2p = .082 (see Figure 4). Perceptual sensitivity diminished over time (a result consistent with traditional vigilance experiments, See et al., 1995), and the participants in the *High Event Rate* condition achieved lower sensitivity scores compared to those in the *Low Event Rate* condition; suggesting that the two conditions differed in difficulty.

Response bias increased significantly across both conditions as a function of period on watch, F(3, 246) = 6.872, p < .001, η^2p = .077. The results did not indicate a statistically significant interaction between condition and period, F(3, 246) = .814, p = .487, η^2p = .010. There were also no significant difference between conditions in response bias, F(1, 82) = 2.233, p = .139, η^2p = .027 (see Figure 5). This pattern indicates that conservatism increased with time on task, but that the levels of conservatism were similar for the two event rate conditions, suggesting that there was no difference between conditions in the participants' willingness to respond.

Perceived Workload and Stress

The results indicated a significant main effect of condition for Global Workload, F(1, 82) = 5.007, p = .028, η^2p = .058, Mental Demand, F(1, 82) = 3.670, p = .059, η^2p = .043, and Performance, F(1, 82) = 5.538, p = .021, η^2p =

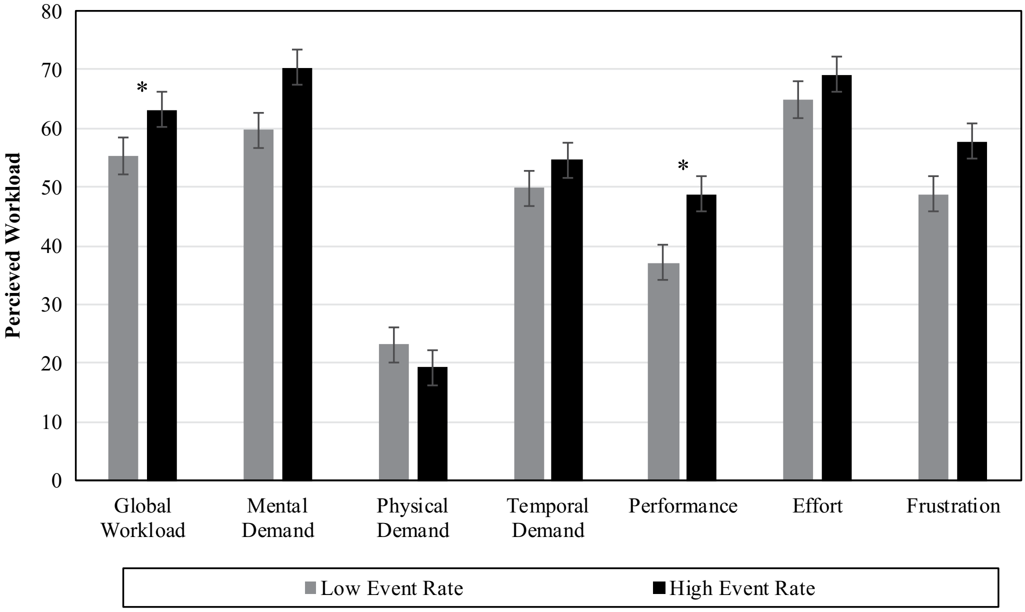

Figure 6. Perceived workload scores as a function of TLX subscales and experimental condition. *Note.* Error bars are standard errors, $^*p < .05$.

.063 (see Figure 6). In each case, the *High Event Rate* condition was associated with higher perceived workload. Overall, Global Workload was above the midpoint (M = 59.24, SD = 16.56), suggesting that participants in both the *Low Event Rate* condition (M = 55.29, SD = 15.54), and the *High Event Rate* condition (M = 63.19, SD = 16.78) found the vigil to be demanding (Grier, 2015). Additionally, Mental Demand, Effort, and Frustration were the greatest contributors to workload, a finding consistent with the overall vigilance research (i.e., Warm et al., 2008) and previous work on the effects of event rate (i.e., Warm et al., 1996).

Across both conditions there were significant differences in the pre-post vigil change scores of task engagement $t(83) = -9.715$, $p < .001$, distress, $t(83) = 9.214$, $p < .001$, and worry $t(83) = -2.865$, $p = .005$ (see Figure 7). Additionally, the results indicated no significant differences between conditions for task engagement, $F(1, 82) = .620$, $p = .433$, $\eta^2 p = .007$, distress, $F(1, 82) = .224$, $p = .637$, $\eta^2 p = .003$, or worry, $F(1, 82) = .695$, $p = .329$, $\eta^2 p = .012$. These results indicate that although the vigil itself was stressful (Warm et al., 2008), there were no differences in perceived stress between the event rate two conditions, a finding consistent with previous work on event rate and vigilance (i.e., Siraj, 2007).

DISCUSSION

The present study utilized a successive cognitive task to further the historical work of Joel Warm. Specifically, the present study extended the previous research on event rate to include how this taxonomic factor influenced detection performance (Warm et al., 1984) and perceived workload and stress (Warm et al., 1996) in a cognitive vigilance task. Across both low and high event rate conditions, performance decrements were observed, congruent with the substantial previous research related to sensory-based vigilance tasks (Warm et al., 2008). This result implies that the vigilance *increment* may not be ubiquitous in cognitive-based vigils (Mouloua & Parasuraman, 1995) as previously believed. Furthermore, the results demonstrated that the present task (i.e., successive, cognitive vigil) produced traditional event rate effects, such that the magnitude of the decrement was directly related to the presentation on nonsignal events. Moreover, clear, significant differences for the proportion of hits, false alarms, sensitivity, and

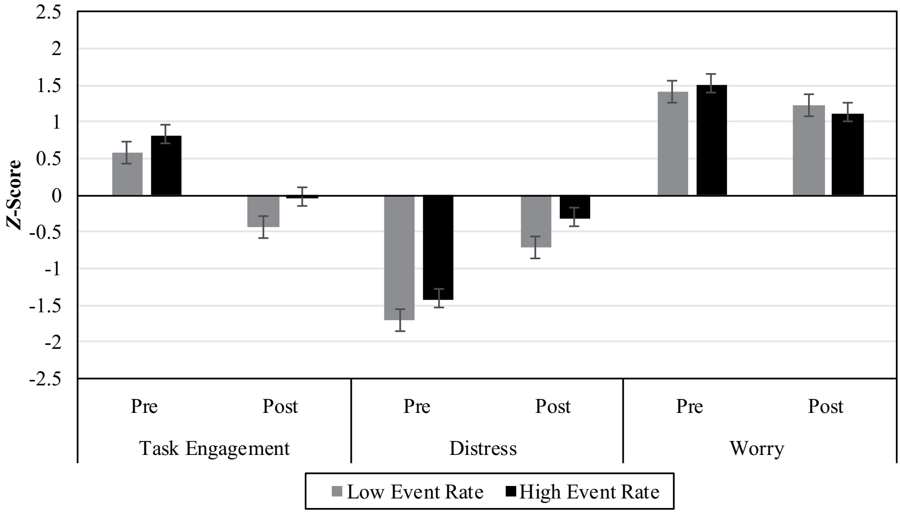

Figure 7. Perceived stress as a function of DSSQ scale and experimental condition.
Note. Error bars are standard error.

perceived workload were observed, suggesting that the two event rate conditions differed in difficulty.

Importantly, most of the results observed in the present experiment were similar to those reported in the previous research (both sensory-based and cognitive-based). For instance, previous research has indicated that event rate is more likely to influence sensitivity than response bias (Guralnick, 1973; Parasuraman, 1979). Moreover, event rate has been shown to be inversely related to sensitivity, such that as event rate increases, the ability to discriminate signals from nonsignals decreases (Guralnick, 1973; Mouloua & Parasuraman, 1995; Parasuraman, 1979; See et al., 1995), which is congruent with the current report.

The results indicated that there were no significant differences in response time between the two event rate conditions, which is consistent with similar research (Meuter & Lacherez, 2016; Siraj, 2007; Smith et al., 2002). Importantly, this suggests that participants had sufficient time to respond to the stimuli, and any change in performance was not produced by a data-limited process associated with differences in ISI durations (Norman & Bobrow, 1975).

The present cognitive-based vigil imposed similar patterns of workload as the traditional sensory-based vigils when accounting for event rate. For instance, previous research has consistently reported a relationship between event rate and perceived workload, such that higher event rates are associated with higher reported levels of perceived workload (Galinsky et al., 1989; Sawyer et al., 2014; Warm et al., 1996)—which was also demonstrated in the present experiment. Moreover, it has been suggested that Mental Demand and Frustration are the main contributing factors to perceived workload on a sensory-based vigilance task when event rate is utilized (Galinsky et al., 1989), however, the present study demonstrated that in addition to Mental Demand and Frustration, Effort was also a significant contributing factor to the patterning of perceived workload on a cognitive-based vigilance task when event rate is employed. This suggests that sensory-based and cognitive-based vigils may produce different patterns of workload; however, further research is needed to explore this claim.

Relatively little is known about how event rate influences perceived stress, as measured by the DSSQ. Limited previous work (i.e., Siraj, 2007), and the present experiment suggest that event rate does not exacerbate the pre-post decline in task engagement or worry, or the pre-post incline in distress. However, as there are so few previous studies that examined the effects of event rate on perceived stress, further work is needed to clarify whether this was an artifact of the present cognitive-based vigil, or if this result is consistent in sensory-based vigils as well.

Implications for the Vigilance Taxonomy

As previously discussed, the current taxonomy of vigilance task performance comprises four factors: source complexity, signal discrimination type, sensory modality, and event rate (Parasuraman & Davies, 1977; Parasuraman et al., 1987). Signal discrimination type typically refers to successive versus simultaneous presentation (Parasuraman & Davies, 1977), however, Parasuraman et al. (1987) also include a sensory versus cognitive distinction as an additional category. The inclusion of a fifth dimension to the current taxonomy based on sensory versus cognitive-based tasks has been suggested as cognitive-based vigils are sometimes associated with an increment function rather than a decrement (Davies & Tune, 1969; Deaton & Parasuraman, 1993; Dember, et al., 1984; See et al., 1995; Warm et al., 1984). It has been suggested that cognitive-based vigils may incur a decrement similar to sensory-based vigils only when there is a sufficient level of task complexity (Noonan, Ash, Loeb, & Warm, 1984, 1985; Parasuraman et al., 1987), such that it is possible to amplify, reverse, or eliminate the decrement depending on the level of task difficulty.

However, Parasuraman et al. (1987) noted that no adequate definition of "complexity" was available to fully understand these effects. In the present study, the traditional decrement function was produced when event rate was utilized as a manipulation of task difficulty. Thus, this gives credence to the notion that cognitive-based vigilance tasks are affected by the increasing demands of information processing associated with event rate in a manner similar to that of sensory tasks. Furthermore, these results indicated that cognitive-based vigilance tasks may produce consistent patterns of performance when differentiated according to the traditional taxonomic categories. Thus, further research on cognitive-based vigilance tasks are needed to determine whether these consistent patterns of performance emerge when performed in conjunction with the remaining taxonomic categories (i.e., sensory modality, source complexity).

CONCLUSION

The purpose of the present experiment was to further examine the effects of event rate on a successive cognitive vigilance task. The results replicated traditional event rate effects (i.e., Jersion & Pickett, 1964; Parasuraman & Davies, 1977; See et al., 1995), such that as event rate increased, the decrement (or decline in performance) became more pronounced. Furthermore, there were clear performance differences in terms of correct detections and false alarms, such that those in the low-event rate condition achieved significantly higher performance than those in the high-event rate condition. Thus, the present study demonstrated that for cognitive-based vigilance tasks, event rate may be used as a manipulation of task difficulty as traditional effects of event rate on the decrement occurred. Moreover, the effects of event rate on response time, signal detection (i.e., sensitivity and response bias), and perceived workload and stress were consistent with the previous findings in sensory-based vigils. This suggests that perhaps cognitive-based vigils are not as drastically different from sensory-based vigils as previously believed, at least in regard to the taxonomic domain of event rate. Future research should further examine how cognitive-based vigilance tasks are affected by the primary factors of the taxonomy (e.g., source complexity) and describe the precise specification of the interrelations between these variables.

AUTHORS' NOTE

Some of the data presented in this manuscript were used in an unpublished doctoral dissertation.

KEY POINTS

- Event rate, or the presentation rate of signals and nonsignals, has been identified as one of the most important factors affecting vigilance performance. However, Warm has suggested that this effect may be limited to sensory-based vigils.
- The present study sought to examine the effects of event rate on a successive cognitive vigilance task in order to further the significant contributions of Warm.

- The results indicated that event rate demonstrated an inverse relationship with performance (i.e., hits and false alarms), such that as event rate increased, overall performance decreased. This finding is consistent with the previous research on sensory-based vigilance tasks.
- Cognitive-based vigilance tasks may produce patterns of performance, workload, and stress similar to traditional sensory-based vigilance tasks.

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